LIX. The After-effect of Movement in the Sense of Touch

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In his study "On the After-Effect of Seen Movement" Wohlgemuth reported a series of 34 experiments, the last one of which was conducted to see whether an after-effect of movement existed in the sense of touch similar to that in the sense of sight.[1] The result was negative, his conclusion being that "under the given experimental conditions, no analogous after-effect of movement exists in the case of touch."[2] In the theoretical sections which follow the experimental, this conclusion was further qualified: "the negative result of this experiment must not be considered as final; some observations made since then show me that the subject is worthy of further investigation."[3]

The present paper reports a series of experiments, which were undertaken in the interests of this problem during the Summer Term of 1921.

Observers.—The *Os* were Miss Catherine Braddock (*B*), fellow in psychology; Dr. Josephine Gleason (*G*), assistant professor of psychology at Vassar College; Dr. Karl M. Dallenbach (*D*), and the author (*T*). When the author observed, Miss Elizabeth Amen, graduate student in psychology, acted as *E*. All the *Os* were trained in introspection. They observed an hour a day, five days a week, and, in so far as it was possible, at the same hour every day. *B* and *G* worked without knowledge of the problem.

Experiments 1 *and* 2

We first sought to reproduce Wohlgemuth's experiments. He gives such a meager account of them, however, that instead of referring to his work we shall give a complete description of the method and procedure which we used.

Method and Procedure—A string-belt of cotton wrapping cord,[4] knotted at intervals of 4 cm., was driven over two horizontal drums at three rates of speed: slow, medium, and fast; moving respectively 7, 14, and 36 cm. per sec.[5] The moving stimulus was applied to the under side of the bare fore-arm, which was smoothly shaved so as to eliminate the drag and pull of the cord on the hairs. The fore-arms were alternately used, in order to exclude, as far as possible, the effects of fatigue and the after-images of pressure; consequently the direction of movement, which objectively was constant from the *Os*' left to right, was alternately ulnar-radial and radial-ulnar. The arm was placed between the two drums, directly over and at right angles to the lower warp of the belt. The hand grasped a support, and, at a given signal from *E*, *O* lowered his elbow to a padded rest, thus bringing his arm into contact with the moving stimulus. The hand-grasp insured the constancy of the place stimulated. To avoid fatigue the position of the hand-grasp, and consequently the position of stimulation, was changed between every two experiments with the same

[1] *Brit. Journ. of Psych.*, Mon. Suppl. 1, 1911, 88, 109.

[2] *Op. cit.*, 88.

[3] *Op. cit.*, 109.

[4] We first tried a silk thread, the "thin silk cord" of Wohlgemuth, but abandoned it as the silk cut the skin and aroused complicating sensations of pain. In its place we used cotton twine, which, being larger and softer, did not have the saw-like effect of the other cord.

[5] Wohlgemuth does not state what speeds he used. He merely says that "various rates" were employed. We do not know, therefore, whether we duplicated his experiments in this respect.

arm. The areas stimulated were restricted to positions between 5 and 20 cm. from the first carpal folds. Three stimulation times, of 60, 120, 180 sec., were used.[6]

The apparatus was so arranged that the movement could be brought to an abrupt end, either with the cord in contact with the arm, or with it forced away from the arm.

In the first series of experiments the cord was forced away; in the second, the cord was allowed to remain in contact with the arm. In each series every stimulation time was used with every rate of movement and the whole repeated 5 times, making a total of 45 experiments for every *O*. The experiments were conducted in haphazard order.

Directions.—The directions used in these experiments were: "At the 'Ready' signal place your arm in position. At 'Now', close your eyes and lower your elbow to the padded rest. A continuous moving stimulus will be applied to your arm. When the objective movement has ceased and the resulting phenomena have run their course, give a complete account of them." These instructions brought out such a great mass of extraneous data regarding the sensations and perceptions aroused during the objective stimulation that the following was added. "Just before the objective movement is stopped *E* will give a second 'Ready, Now' signal. Give particular attention in your report to the phenomena, if any, which occur after the objective movement ceases."

Results.—Nothing was said in the instructions about after-images of movement; indeed, as we observed above, two of the *O*s worked without knowledge of the problem. We expected, nevertheless, since the *O*s' attention was directed to the interval immediately following the objective movement, that reports of negative after-effects would be given if such phenomena occurred. And such phenomena did occur. All *O*s reported instances in which the objective movement was followed by a movement in the opposite direction. The percent. of times these negative after-images of movement were reported is shown in Tables I and II. The results of the first series of experiments, those in which the cord was removed from the arm, are shown in Table I; the results of the second series, those in which the cord was allowed to remain in contact with the arm, are shown in Table II.

TABLE I

Showing the percent. of times that an after-effect of movement was observed when the cord was removed from contact.

	Rate	Slow			Medium			Fast		
	Time in sec.:	60	120	180	60	120	180	60	120	180
	B	20	40	40	20	60	40	0	0	20
	D	0	0	0	0	0	0	0	0	0
O	G	0	0	0	0	0	0	0	0	0
	T	0	0	0	0	0	0	0	0	20

TABLE II

Showing the percent. of times that an after-effect of movement was observed when the cord was allowed to remain in contact.

	Rate	Slow			Medium			Fast		
	Time in sec.:	60	120	180	60	120	180	60	120	180
	B	40	40	0	40	60	40	20	20	40
	D	20	0	0	20	20	0	0	0	20
O	G	20	0	0	0	20	0	0	0	20
	T	0	0	0	0	20	20	0	20	20

[6] Again, Wohlgemuth is not explicit; he merely reports "the experiments lasted from 1-3 minutes." *Loc. cit.*

In the experiments of Series 1, only two *Os*, *B* and *T*, reported the after-effect; but in Series 2, all *Os* reported it. The experiences were variously described as a "jerk backwards," a "slow movement backwards," a "diffuse drift backwards," a " backward wave-like movement," a "reverse movement," a "backward movement," and a "backward brush or sweep." The rate, extent, and duration of the subjective movement varied considerably: it was described as rapid and as slow; as large and as small; as of long duration and as of short.

The after-effect was noted more frequently when the stimulus was allowed to remain in contact with the arm than when it was removed; more frequently when the medium rate of movement was used than when either the fast or the slow rate was employed; and more frequently when the stimulus was applied for 120 sec. than when it was applied for the longer or shorter intervals.

We recognize that the negative after-image of movement occurred too infrequently in our experience to permit of our drawing conclusions regarding the conditions of its appearance. Our only claim is that our results demonstrate the existence of an after-effect of movement in the sense of touch analogous to that in the sense of sight.

Compulsory conditions were not obtained for any of the *Os*. The closest approach was with *B*, who reported the negative after-effect in both series of experiments in 60% of the cases when the medium rate of movement and the 120 sec. stimulation were used. That we did not obtain compulsory conditions we believed to be due to the fact that only small areas of the skin, areas approximately 1 mm. x 30 mm. in extent,[7] were stimulated. It is true, as our results themselves demonstrate, and as Wohlgemuth clearly showed in the field of vision, that an after-effect may be obtained when the objectively moving stimulus is confined to very small areas; but there is nothing in our results, nor, as we read Wohlgemuth, is there anything in his results,[8] that would lead us to believe small areas are as compulsory as large. In the endeavor, therefore, to obtain compulsory conditions and to examine the effect of size upon the illusion, we increased, in the following experiments, the dimensions of the stimulus.

Experiments 3 and 4

Method and Procedure.—In experiments 3 and 4 the width of the stimulus was increased by replacing the string belt by a muslin band 12 cm. wide. The apparatus used in Experiments 1 and 2 was otherwise unchanged.

The method of procedure, however, was changed. (1) Five stimulation times of 10, 20, 30, 60 and 120 sec. were employed instead of three; and (2) the number of repetitions was reduced from five to three. The stimulation times were increased in number in order that a greater temporal variation might be obtained and the effect of duration be more easily observed. The extreme stimulation of 180 sec. was omitted because we found that it was not as effective as the 120 sec. interval. The number of times the various experiments were repeated was reduced to three because of pressure of time.

[7]The diameter of the cord was 1mm. The length of the area stimulated varied for the different *Os*; 10 successive measurements for every *O* gave the following: *B*, 32 mm. ± 3.1; *D*, 39 mm. ± 3.7; *G*, 31 mm. ± 3.0; *T*, 30 mm. ± 2.5.

[8]One of Wohlgemuth's experiments—the 23rd—was undertaken "for the purpose of examining Exner's statement that an after-effect is only produced by moving surfaces of some size" (*op. cit.*, 73). Wohlgemuth used surfaces as small as 0.075 mm. x 5 mm. and found that negative after-effects were still produced. He did not, however, quantify his data, or compare the after-effect produced by small areas with that produced by large.

In the experiments of Series 3 the cloth band was removed from the arm when the objective movement ceased; in those of Series 4 it was allowed to remain in contact with the arm.

Results.—All of the *Os*, in both series of experiments, reported the negative after-effect of movement. The same descriptive terms were used as before.

In the experiments of Series 3, those in which the belt was removed from the arm, a new after-effect was reported, which, like Benussi's loop and bow movements,[9] seemed to leave the skin. It was described in such terms as: "movement away," "movement off," "movement from." We do not know whether these experiences were the result of the sudden formation of a negative pressure gradient, or of a stimulus-error; it may suffice at present to note that they occurred, and that they were not classified with the negative after-images of movement with which we are now concerned.

There was little difference in the results between the two series of experiments, or among the various speeds of stimulation. The differences among the stimulation times, however, were quite marked: the 10 and 20 sec. stimulations gave very few negative after-effects,—none in fact for *D* and *G*,—whereas the longer stimulation times gave the after-effect in 33, 22, 26, and 32 percent. of the experiments for *B*, *D*, *G*, and *T* respectively. At these longer intervals, the cases occurred about equally often.

The negative after-effect of movement was reported more frequently in these experiments than in those of Series 1 and 2, but still compulsory conditions were not obtained. An increase of width alone was not sufficient; therefore, in the following experiments, the length of the area stimulated was also increased.

Experiments 5 *and* 6

Method and Procedure.—The apparatus in experiments 5 and 6 was adjusted so that the stimulus could be applied longitudinally. A rest, supporting the arm at the hand and elbow, was built over one of the drums at an angle of about 45°, so that the rotating belt could be raised or lowered by means of a movable table pivoted at the lower end of the rest, and contact with the arm could thus be made or broken. The belt, 12 cm. wide, made of the coarsest corduroy obtainable, was driven at the same three rates of speed used in the previous experiments. The shaved under surfaces of the forearms were alternately used. The direction of movement was peripheral, from elbow to wrist. Three stimulation times of 30, 60 and 120 sec. were employed. The length of the stimulated areas was approximately 18 cm., the width, that of the forearm. In the experiments of Series 5, the table was lowered and the belt was allowed to fall away from the arm; in those of Series 6, the movement was abruptly stopped and the belt allowed to remain in contact with the arm. In each series every stimulation time was used three times in haphazard order with every rate, thus making a total in each series of 27 experiements for every *O*. The same instructions were used as in the previous experiments.

Results.—As in the other experiments, all *Os* reported the negative after-image of movement. More cases were reported in these than in any of the previous series. Their distribution shows that the stimulus was more effective when it remained in contact with the skin after the interruption

[9] V. Benussi, Kinematohaptische Erscheinungen, *Arch. f. d. ges. Psych.*, 29, 1913, 385; Kinematohaptische Scheinbewegung und Auffassungsumformung, *Ber. ü. d. VI. Kong. f. exp. Psych.*, 1914, 31; Versuche zur Analyse taktil erweckter Scheinbewegungen, *Arch. f. d. ges. Psych.*, 36, 1916, 59.

of the objective movement than when it was removed; and furthermore, that there was little difference among the rates and the times of stimulation, —what little advantage existed was, however, in the direction of the faster rates and the longer times.

Though more reports of the after-effect were given in these experiments than in any of the previous ones we still failed to realize compulsory conditions. This failure we believed to be due to the inadequacy of the stimulation. The corduroy belt, on which we had set great hope, proved unsatisfactory. It was so soft and smooth, and the corrugations were so close together, that the *Os* frequently had difficulty in perceiving movement even during the objective stimulation; at times the movement adapted out and only a dull pressure remained; at other times, when the objective movement was perceived, the direction shifted.[10] It was not unusual for the *Os* to report that the direction had fluctuated 3 or 4 times during the course of a single stimulation. It was indeed surprising that so many reports of the after-effect were obtained under such poor conditions. In view of these facts, we decided to repeat the experiments with a more effective stimulus.

Experiments 7 and 8

Method and Procedure.—In experiments 7 and 8 a coarsely corrugated muslin cloth was used in place of the corduroy. The corrugations were made by sewing small pieces of cloth 2 cm. wide at separations of 4 cm. across the belt. The apparatus used in Experiments 5 and 6 was otherwise unchanged.

The method of procedure, however, was altered in two respects. (1) The direction of the movement was changed from peripheral to central; and (2) only two rates of stimulation were employed, which we shall designate, to bring them into line with the rates already used, as 'fast' and 'very fast'. The rate of movement during the 'fast' stimulation was 39 cm. per sec., approximately the 'fast' speed used in the other experiments; that during the 'very fast' stimulation was 109 cm. per sec., approximateiy three times the speed of the 'fast' rate. Otherwise the same procedure was followed as in Experiments 5 and 6. The instructions were not changed.

In the experiments of Series 7, the belt was allowed to fall away from the arm; in those of Series 8 the movement was stopped while the belt remained in contact with the arm.

Results.—The percent. of times that the negative after-effect of movement was reported in these experiments is shown in Tables III and IV.

TABLE III

Showing the percent. of times the after-effect was reported when the belt was allowed to fall from the arm, distributed according to the rate of the objective movement and the duration of the stimulation.

	RATE	FAST			VERY FAST		
	Time in sec.:	30	60	120	30	60	120
	B	100	100	100	33	33	33
O	G	33	33	67	100	33	67
	G	33	33	67	100	100	0
	T	0	0	0	67	33	100

[10]These experiences were analogous to those in the Bourdon illusion. *Cf.* B. Bourdon, *La perception visuelle de l'espace*, 1902, 176, 194.

TABLE IV

Showing the percent. of times the after-effect was reported when the belt was allowed to remain in contact with the arm, distributed according to the rate of the objective movement and the duration of the stimulation.

	RATE	FAST			VERY FAST		
	Time in sec.:	30	60	120	30	60	120
	B	67	67	100	100	67	67
	D	67	100	100	33	67	100
O	G	33	100	100	100	100	100
	T	0	0	67	33	100	100

These tables show that compulsory conditions were obtained for all *Os*. Certain combinations of rate and duration, more or less peculiar to every *O*, invariably produced the negative after-effect. Though the distribution of the cases seems to indicate a tendency for the phenomenon to occur at the faster rates and the longer durations, we recognize that too few experiments were performed to justify us in drawing any general conclusions regarding these variables.

We feel justified, however, in concluding, from the data at hand, that the conditions are more compelling for the perception when the stimulus is not removed from the arm; that, in other words, pressure stimulation continued after the cessation of the objective movement is conducive to the perception of the negative after-effect. This conclusion is warranted not only by the fact that compulsory conditions were obtained more frequently when the belt was allowed to remain in contact with the arm than when it was removed, as shown in Tables III and IV, but also by the fact that more cases of the after-effect were reported in the experiments of Series 8 than in those of Series 7. Indeed, this conclusion is corroborated by the results of all our experiments: more cases of the after-effect were reported, as is clearly shown in Table V, in the experiments of Series 2, 4, 6, and 8, *i. e.*, in those in which the stimulus was allowed to remain in contact with the arm after the objective movement had ceased, than in those of Series 1, 3, 5, and 7, the series in which the objective stimulus was removed.[12]

TABLE V

Showing the number of times the after-effect was reported in the different experiments: those in which the stimulus was removed, and those in which it was allowed to remain in contact with the arm.

REMOVED		CONTACT	
Exp.	Number times after-effect reported	Exp.	Number times after-effect reported
1	13	2	26
3	19	4	28
5	17	6	28
7	40	8	53
Total	89	Total	135

[12]A total of 1080 experiments was performed. Half were performed with the stimulus removed, and half, under otherwise identical conditions, with the stimulus continued in contact after the objective movement had ceased. When the stimulus was removed the after-effect was reported 89 times, in 16 percent. of the experiments; when contact was continued the after-effect was reported 135 times, in 25 percent. of the experiments. This difference is too large to be due to chance.

These results accord with those of Wohlgemuth in the field of vision. Wohlgemuth found "that it is far more difficult to discover the after-effect in the subjective field of vision than in the objective. In other words, the after-effect is more easily discovered if the field of vision is filled."[13] By 'subjective', Wohlgemuth means the field of vision when the objective movement is interrupted by closing the eyes,—a condition comparable to the removal of the cutaneous stimulus; by 'objective', he means the field when the movement has stopped and the eyes are open and focused upon the fixation point,—a condition comparable to the retention of the static cutaneous stimulus on the skin.

Experiment 9

In order to ascertain the effect of movement upon some other area of the body a few experiments were conducted upon the calf of *T*'s leg. This part of the body was chosen as it was the only other area that could be stimulated without radically altering the apparatus. Mr. W. A. Andrews, a graduate student in psychology, acted as *E* during these observations.

With the exception that the direction of the movement was peripheral, from the knee towards the foot, the apparatus was used exactly as in Experiments 7 and 8.

Results.—The results of the previous experiments were confirmed. Negative after-images were again reported. As far as *T* was able to discern, the after-effect on the leg was as pronounced as that upon the fore-arm. These results, therefore, lead us to believe that an after-effect of movement may be obtained in the sense of touch from any part of the body that is adequately stimulated.

Experiment 10

After we had obtained compulsory conditions, a few experiments were performed in which the *O*s were asked to describe the negative after-effects in strictly psychological terms.

The apparatus and method used in Experiments 7 and 8 were again employed.

The instructions were altered to read as follows: "In the previous experiments you reported negative after-images of movement. You are now to concentrate upon the description of these processes. At 'Ready, Now' the objective movement will cease; when the resulting phenomena have run their course, describe the processes in strictly psychological terms."

Results.—An analysis of the introspections yielded the following results.

(1) The negative after-images of movement were variously localized by the different *O*s. At times the *O*s reported that the movement was cutaneous, at times that it was subcutaneous, and at other times a combination of the two. Excerpts, selected by way of illustration, are:

(*B*) "Creeping along *surface.*"
"Movement uniform, smooth, weak, *subcutaneous.*"
"Movement *cutaneous as well as subcutaneous.*"
(*D*) "Light, filmy pressures which seemed to *envelop the arm* and float toward the wrist."
"Weak, light pressure, like puff of air moving on *surface of skin* with a duller, deader, *deeper,* more diffuse *pressure below the skin.*"
(*G*) "Even pressure moving *along arm.*"
"Flow of pressure *through* the arm."
"Bright, tingling pressure which moved *down the arm,* accompanied by a dull pressure which was *deeper* within the skin."

[13] *Op. cit.,* 31, 111.

(*T*) "Impression of movement floating *along* arm."
"Movement seemed to be *in, rather than along,* the arm."

(2) The quality of the after-effect varied with the localization. When localized in the cutaneous tissues, the after-images were described as "bright tickle," "light contact," "lively pressure;" when localized in the subcutaneous tissues, they were described as "vague," "dull," "dead," "deep," pressures. Examples are chosen from the reports of *D* and *G:*

(*D*) "After-effect of movement good..... Quality of the after-images *bright, lively pressure,* and *deep, dull, diffuse pressure.*"
"*Bright tickle* sensations which moved along the surface of the skin."
"*Light* superficial *contact* which seem to float along skin."
(*G*) "After the objective movement ceased at first perceived a *bright, lively pressure* which seemed to shift toward the wrist; then a *vague, dull pressure* localized deeper within the arm."

(3) The interval between the cessation of the objective stimulation and the appearance of the after-effect varied considerably in length. At times it was very short, and the negative after-images seemed immediately to occur:

(*D*) (The objective movement was) "*immediately* followed by a short jerk backwards."
(*T*) "Movement perceived *as soon as* objective movement ceased."

At other times it was longer, and the negative after-images were slow in appearing:

(*D*) "Light, filmy pressures which seemed to.....float toward the wrist, *slow* in appearing."
(*G*) "Dull pressures, seemed to shift toward wrist, came on more *gradually* than usual."

(4) The intensity, duration, rate, clearness and extent of the negative after-images likewise varied. At times the subjective movement was described as "intense" and "strong;" at other times as "weak," and "slight." At times it was reported to have "faded out very quickly" (*B*), to have been "of very short duration" (*D*), and to have "lasted just for a moment" (*G*); at other times it was reported to have "decreased slowly" (*B*), to have "long continued" (*D*), to have been of "long duration" (*G*), and to have "slowly faded" (*T*). The rate of the subjective movement was described as "rapid," "average or medium," and as "slow." At times the clearness was maximal, "as clear as if the cloth had been set going backwards" (*D*); at other times it was minimal: "the movement obscure, would not have observed it had I not been set for it" (*D*). The extent of the after-movement was at times definite: "the moving area was sharply and clearly defined" (*T*); but for the most part the extent was "diffuse," "ill defined," and "ill localized."

(5) The existential correlate of the perception of the negative after-image of movement appears to be an integration of spatial, intensive, and temporal aspects of the cutaneous or subcutaneous pressure sensations. The introspections upon which this statement is based are:

(*D*) "Slow backward movement along the surface of the arm. Bright lively pressure. The cutaneous sensations fluctuate spatially and temporally in intensity; by that I mean the cutaneous sensations, which are present over the whole area stimulated, rise and fall in intensity in a regular temporal and spatial sequence. The experience is clear, but very difficult to describe in attributive terms."
(*G*) "Dull pressure; movement gradual, seems to be spatial shift of intensity; quality did not change, it was the same dull pressure throughout."

" 'Running' on skin. The 'running' is a rapid spatial shift, changing in intensity."

Our analysis agrees very closely with that of Whitchurch given in her study on the illusory perception of cutaneous movement. Whitchurch found that the perception of movement obtained by stimulating adjacent pressure spots could be described as "an integration of quality, time, and cutaneous extent."[14] For methods which differ so widely, the descriptions are remarkably alike. If the difference is a true difference; if movement may in one instance be a qualitative integration with time and extent, and in another an intensive integration with time and extent; then we have further evidence that the meaning of movement "may be carried by several existential correlates."[15]

SUMMARY

(1) Repetition of Wohlgemuth's work showed:
(*a*) that his apparatus was inadequate to the problem;
(*b*) that even under the unfavorable conditions of his experiment, all the *Os* reported an after-effect of movement in the sense of touch analogous to that in the sense of sight;
(*c*) that the after-effect was noted more frequently when the stimulus was allowed to remain in contact with the arm than when it was removed;
(*d*) that only a very small area of the arm was stimulated;
(*e*) that the apparatus must be modified, if compulsory conditions are to be realized, so that more effective stimuli can be applied.

(2) Experiments with the modified apparatus showed:
(*a*) that an increase of width alone is not sufficient to produce conditions compulsory to the after-effect;
(*b*) that an increase of width and length is still inadequate to the compulsory perception, if the stimulus is soft and smooth;
(*c*) that compulsory conditions are obtained when the fore-arm is longitudinally stimulated by a rough and coarsely corrugated linen band;
(*d*) that conditions are more compelling when the stimulus is not removed; that, in other words, pressure stimulation continued after the cessation of the objective movement is conducive to the perception of the negative after-effect.

(3) Experiments upon the calf of the leg showed:
(*a*) that the negative after-effect is as pronounced on the leg as upon the fore-arm;
(*b*) that the same general conditions obtained as upon the fore-arm.

(4) The experiments performed for the processual description of after-effect revealed:
(*a*) that the processes are at times cutaneous, at times subcutaneous, and at other times a combination of the two;
(*b*) that the quality varies with localization from "bright tickle," "light contact," "lively pressure," to "vague," "dull," "dead," "deep pressure;"
(*c*) that the interval between the cessation of the objective stimulation and the appearance of the after-effect is not constant; at times it is very short, at other times long;
(*d*) that the intensity, duration, rate, clearness and extent of the negative after-images vary; and
(*e*) that the after-effect is an integration of intensity, time, and cutaneous extent.

[14] A. K. Whitchurch, The Illusory Perception of Movement on the Skin, this JOURNAL, 32, 1921, 488.

[15] *Op. cit.*, 489.